

The Gulf of Guinea goby-shrimp symbiosis and a review of goby-thalassinidean associations

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An undescribed species of the family Gobiidae shares the burrows of the axiid shrimp *Axiopsis serratifrons* at São Tomé and Príncipe (central eastern Atlantic). In contrast to similar associations of gobiid fishes with alpheid shrimps in the Indo-Pacific and the western Atlantic (where the goby serves as a sentinel for the crustacean and the shrimp leaves the burrow only if the goby remains at the burrow entrance), the axiid appears to completely ignore the goby, which rests near the opening of the burrow. Facultative and obligatory associations of gobies with thalassinidean shrimps are reviewed.

Key words: Axiidae, convergent evolution, Gobiidae, São Tomé and Príncipe, symbiosis

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INTRODUCTION

Almost 130 species of gobies (Pisces Gobiidae) from 20 different genera live in symbiosis with pistol shrimps of the genus *Alpheus* in the Indo-Pacific (reviews by Karplus 1987; Nelson [cited 2008]). In some goby genera, like *Amblyeleotris* or *Cryptocentrus* for instance, all known species are associated with pistol shrimps. More than 30 different *Alpheus* species live with these gobies (A. Anker, pers. comm.). The shrimp constructs a burrow in the sand or gravel and continuously keeps it clean from sediment seeping in. The goby uses this tunnel as a refuge and to sleep in it. This association is advantageous for both partners. The pistol shrimp uses the goby as an early warning system. The shrimp leaves the burrow only when the goby remains near the entrance and uses one of its two antennae to permanently maintain contact with the fish. If the fish indicates danger by fluttering the caudal fin or even by fleeing into the tunnel the shrimp rapidly retreats. In the popular aquarium literature in English and German, these goby species are called "watchman gobies" (Wächtergrundeln).

Most *Alpheus* species with gobies as tenants live in pairs. Frequently a single goby is seen with a pistol shrimp but sometimes two gobies associate with *Alpheus* shrimps. Many of these associations are obligatory, that is goby and shrimp are always encountered together, never alone. Some of these gobies live exclusively with certain *Alpheus* species, others can occupy the burrows of several shrimp species. In the pistol shrimps as well, some *Alpheus* species live only with a certain goby, while others can be encountered with several different goby species.

In the tropical western Atlantic, the gobies *Nes longus* and *Ctenogobius saepepallens* live with the pistol shrimp *Alpheus floridanus*, occasionally also the gobies *Gobionellus stigmalophius* and *Bathygobius curacao* (Karplus 1992; Randall et al. 2005). While *Nes longus* and its shrimp show a relation similar to the Indo-Pacific symbioses described above, the relation between *Ctenogobius saepepallens* and the alpheid shrimp is much looser: the shrimp emerges also when the goby is not present at the burrow opening and there is no antennal contact when the goby is present; neither does the goby

communicate danger with caudal fin fluttering. No goby-alpheid associations have been reported from the eastern Atlantic.

This work describes a new goby-shrimp symbiosis at the islands of São Tomé and Príncipe (Gulf of Guinea), in the eastern central Atlantic. A preliminary popular account of this association, containing colour photos, was given by Wirtz (2005).

MATERIAL AND METHODS

Initial observations were made during four SCUBA dives in the area of Bom Bom Islet, north coast of Príncipe Island (01°41'N - 07°24'E) in February 2004. Additional observations were made during three SCUBA dives at the coasts of São Tomé Island, namely Diogo Vaz (00°19'N - 06°29'E) and Santana Islet (0°15'N - 06°46'E) in February 2006. Observations on the behaviour of the fish and shrimp were mostly done at Diogo Vaz. As these were done at 24 m depth, and only two dives were performed, the total time spent on observation was approx. 30 minutes. The remainder dives at São Tomé was spent attempting to collect specimens.

Two specimens of the goby were captured (one at Diogo Vaz and one at Santana islet) with the help of rotenone. They are now deposited in the collection of the Zoological Museum at Munich, Germany (ZSM 34186, Diogo Vaz) and in the collection of the Universidade Federal de Espírito Santo, Vitória, Brasil (UFES 133, Santana islet).

Two specimens of the crustacean were caught at Diogo Vaz in 24 m depth by shooting a harpoon into the entrance of the cave when the crustacean was outside. They are now in the collection of the Natural History Museum at Vienna, Austria (NHMW 21950).

RESULTS

SPECIMENS IDENTIFICATION

The crustacean and the goby both reach a length of about 5 centimetres. The two specimens of the goby that were captured have been examined by U. Schliewen and M. Kovačić. These experts

regard it as an undescribed species of the family Gobiidae and are planning to describe the species in the genus *Didogobius* (pers. comm.). The crustacean has been identified by Peter Dworschak (pers. comm.) as *Axiopsis serratifrons* (A. Milne Edwards, 1873), family Axiidae, infraorder Thalassinidea – a species widespread on both sides of the Atlantic, Indian, and Pacific Oceans.

THE HABITAT

The approximately 40 burrows of *Axiopsis serratifrons* observed at Príncipe and at São Tomé were on sandy bottoms that contained small stones, fragments of coral and shells, from about 7 m downwards to 25 m. No burrows were seen on pure sand. Some were seen on bottom consisting of larger stones with small patches of sandy areas between them. The burrow opening of about 3 cm diameter is stabilized by pieces of rubble or shell fragments. This corresponds to descriptions by Dworschak & Ott (1993) and Dworschak (2004) for *A. serratifrons* burrows in the Caribbean.

THE RELATION BETWEEN THE FISH AND THE CRUSTACEAN

A single goby and a single shrimp were observed associated in all cases; no pairs of either the shrimp or the goby were recorded but a second animal might have been hidden in the burrow (Dworschak & Ott 1993, record that *Axiopsis serratifrons* usually lives in pairs). Like pistol shrimps of the genus *Alpheus*, *A. serratifrons* frequently came out of the tunnel, transporting sediment, usually small stones. The crustaceans observed walked as far as two to three body lengths away from the burrow opening, dropped the stone and re-entered the burrow. In contrast to the *Alpheus* species, they did not maintain contact to their fish partner with an antenna when outside the burrow (see Fig. 1). Frequently the shrimp came out of the burrow before the goby. In two burrows observed for about 10 minutes each, the shrimp several times appeared and re-entered the burrow without any goby appearing: no goby probably was associated with these two shrimps. In contrast, no goby was seen without an associated *Axiopsis serratifrons*.



Fig. 1. Above, the undescribed goby in front of an *Axiopsis serratifrons* burrow; the shrimp is visible at the entrance. Below, the shrimp is carrying a stone out of the burrow; it does not maintain antennal contact with the goby, which rests in the entrance of the burrow.

When a diver approached slowly, the goby did not give any warning signals such as tail flicks but at some point rapidly disappeared into the burrow. The *Axiopsis* then also retreated, after the goby. It was not clear if the retreat of the goby did or did not cause the retreat of the shrimp.

DISCUSSION

Apparently a goby-shrimp association, similar to that between gobies and pistol shrimps of the genus *Alpheus* in the Indopacific and in the western Atlantic, has evolved again and completely independently in the eastern Atlantic. The relation between the undescribed goby and the axiid shrimp *Axiopsis serratifrons* at São Tomé and Príncipe does not appear to be as tight as that between Indopacific guardian gobies and their pistol shrimps. Perhaps the goby has only moved into a convenient hole in the ground and, as it does not cause any damage to the axiid, is tolerated but largely ignored by the crustacean. The more evolved relation between most guardian gobies and their pistol shrimps may have started in such a way at some time in the past: in a second step, the pistol shrimps then learned to interpret and to exploit the behaviour of the goby (Karplus 1987, 1992; Randall et al. 2005).

Axiopsis serratifrons is a circumtropical species; it has never been observed with gobies in other areas, even when resin casts of the burrow were made (Dworschak & Ott 1993). The undescribed goby has so far only been recorded at São Tomé and Príncipe islands but because of the great similarity in their fish faunas (Wirtz et al. 2007; Floeter et al. 2008), it might well also occur at the Cape Verde islands, where *A. serratifrons* is known to live (Abed-Navandi 2000).

Several other associations of gobies with thalassinidean shrimps have been reported from other areas. In some of these, the goby appears to co-occupy a thalassinidean burrow only for a short term, in others it appears to permanently live in the burrow as an adult.

The goby *Clevelandia ios* uses the burrows of *Calianassa affinis* and *Calianassa californiensis* and *Upogebia pugettensis* only briefly as a place of refuge either from predators or during tidal exposure (MacGinitie 1939; MacGinitie &

MacGinitie 1968; Hoffman 1981). The shrimps were often observed chasing the gobies out of the burrows (Hoffman 1981). The case of the goby *Lepidogobius lepidus* occasionally encountered with *Upogebia pugettensis* is quite similar: gobies are in the burrows only occasionally and the shrimps have been observed chasing the goby out of the burrow (Grossman 1979; Hoffman 1981). Kinoshita (2002) records an individual of the goby species *Chaenogobius macrognathos* from 24 burrows of the thalassinidean *Upogebia major* in Japan; as only a single association was recorded, this could be an artefact and the observation needs verification. The Japanese gobies *Gymnogobius cylindricus*, *G. uchidai*, *G. scrobiculatus*, and *Eutaeniichthys gilli* live on mud flats and can be encountered in the burrows of *Upogebia major* (Senou 2004; Suzuki et al. 2006) but no studies on these species are available.

A single animal or a pair of the goby *Austrolethops wardi* was encountered by Kneer (2006) in three of five burrows of *Neaxius acanthus* in Indonesia; the goby apparently does not leave the burrow of the shrimp but does not appear to have any obvious morphological adaptations to its way of life, such as reduced eye size (Kneer et al. in prep). MacGinitie (1939) describes the biology of the blind goby *Typhlogobius californiensis*, which lives in pairs, deep in the burrow of pairs of *Callianassa affinis* (now called *Callianassa biffari* Holthuis 1991, Dworschak pers. comm.) in California; the blind gobies do not leave the burrow of the crustacean. Itani & Tanase (1996) recorded the blind goby *Luciogobius pallidus* from the burrow of *Upogebia yokoyai* in Japan, but only a single goby was encountered in about 100 burrows investigated, and the presence of a shrimp was not checked (Itani, pers. comm.).

The occurrence of at least two species of blind gobies in the burrows of thalassinideans suggests an alternate evolutionary scenario to the one described above: instead of developing into a “watchman goby – shrimp symbiosis”, a goby – thalassinidean association might develop in such a way that the goby spends more and more time inside the burrow of the shrimp, finally adapting to this cave-like environment morphologically.

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